UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Cosmic Rays

2627-1-F5803Q013

Aims

The learning outcomes of this course include components of acquisition of both specific knowledge and skills and development of transversal skills.
The objective of acquiring specific knowledge and skills concerns the physics of cosmic rays and their relevance in astrophysics, the sources of production, the environments and the propagation processes. For some topics, practical examples and numerical exercises will be proposed.
The objective of acquiring transversal skills includes:

- critical capacity, for example, evaluating the impact of cosmic rays and related processes in very different fields and contexts, not only from a physics point of view but also for the practical implications;
- the ability to communicate, through the choice and preparation of a presentation for the exam;
- the ability to continue the study independently, having provided the student with the updated framework of frontier research in this field and the possible applications.

At the completion of the course the students will know:

- the main observational properties of cosmic rays and how they are detected
- the main sources of cosmic rays and their properties
- how to describe the propagation of cosmic rays in space
- the connections between cosmic rays, cosmology and fundamental physics
- the properties of space environment and the radiation risk

Contents

Cosmic rays (CR) are described in relation to observations, their composition and properties. Main topics are: origin and astrophysical sources of CR; acceleration processes; interaction with interstellar medium; propagation in the Milky Way; interaction with solar wind; propagation in the heliosphere; interaction with the Earth magnetic field and

atmosphere; CR studies in relation to fundamental physics, cosmology and astrophysics.

Detailed program

- **Observational properties of Cosmic Rays**:
  content: spectral intensity, energy density and composition. Main scientific results observing CR, current experimental activities from the ground and in space.
  skils: techniques and strategy for cosmic rays observation.
- **Origin of Cosmic Rays**:
  content: acceleration processes, galactic and extragalactic astrophysical sources.
  skils: physical mechanisms of energy transfer from and to cosmic rays.
- **Interaction of CR with interstellar medium and propagation in the Milky Way**:
  content: diffusive models and confinement processes, energy loss processes and electromagnetic radiation from CR, spallation processes and secondary component production.
  skils: solutions for diffusion equation; numerical codes of CR propagation in the ISM.
- **Interaction with solar wind and solar modulation**:
  content: solar magnetic activity, solar particle emission, the structure of heliosphere.
  skils: solutions for the transport equation; numerical codes of propagation in heliosphere.
- **Interaction with Earth magnetic field and atmosphere**:
  content: radiation belts and geomagnetic cut-off, extensive air showers and observations of highest energy CR.
  skils: space environment and radiation risk; CR tracing in the magnetic field; Extensive Air Showers tecniques.
- **Relevance of Cosmic Rays for fundamental physics and cosmology**:
  content: new physics research, production details in stellar nucleosynthesis, Dark Matter, Cosmologic Anti-matter, CRs of extragalactic origin.

Prerequisites

knowledge of the basic physics courses provided in the bachelor degree

Teaching form

All lessons are held in person, in english, in delivery mode:

- 21 2-hour lessons held in presence mode.
- on motivated request live streaming will be activated.

Textbook and teaching resource

Reference textbooks and resources:

1. Slides and notes of the lectures, provided by the lecturer.

2. High Energy Astrophysics, M.S. Longair, Cambridge University press, third edition, ISBN 978-0-521-75618-1;
3. Space Physics – An introduction, C.T. Russel, J.G. Luhmann, R.J. Strangeway, Cambridge University press, ISBN 978-1-107-09882-4.

Semester

Second semester: from beginning of March to beginning of June 2026

Assessment method

Final evaluation, with a score up to thirty, through an oral interview on the topics covered in class.
Students will be asked to prepare a presentation through which to present and discuss a topic of their choice from the course. The student's maturity, mastery of the subject exposed and clarity and property in the language will be assessed. Furthermore, the critical ability of the student will be assessed, through the connections between the topic discussed with other topics included in the class and to general topics among those treated in the degree course.

Office hours

Tentatively every working Friday during the course, from 12:30 pm to 1:30 pm. Otherwise on request. This calendar is depending on the final lectures timetable.

Sustainable Development Goals

QUALITY EDUCATION | INDUSTRY, INNOVATION AND INFRASTRUCTURE | CLIMATE ACTION